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Procedia Computer Science 100 (2016) 1163 – 1167

Procedia Computer Science

Conference on ENTERprise Information Systems / International Conference on Project MANagement / Conference on Health and Social Care Information Systems and Technologies, CENTERIS / ProjMAN / HCist 2016, October 5-7, 2016

SAR Interferometry Technique For Ground Deformation Assessment On Karazhanbas Oilfield

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Abstract

This paper briefly presents advantages of SAR interferometry for displacement monitoring using StaMPS/MTI software over areas of intensive hydrocarbon extraction with complicated geological conditions. The Karazhanbas field is a giant oil field in Western Kazakhstan, which was discovered over 35 years ago. The subsidence over Karazhanbas field was measured by using interferometric analysis of SAR (Synthetic Aperture Radar) archive data. The used dataset consist of 34 Envisat images acquired from 2003 to 2009. Deformation maps of the study area were produced.by using Persistent Scatterers (PS) and Small Baseline Subset (SBAS) methods In the future, the experimental results of observation will be continued with Sentinel 1A data. The archive for 2015-2016 years of Sentinel-1 mission, specifically designed for surface deformation monitoring over large areas, affords us the opportunity to further researches.

Peer-review under responsibility of the organizing committee of CENTERIS 2016

Keywords: StaMPS/MTI; Envisat; SAR Interferometry

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Peer-review under responsibility of the organizing committee of CENTERIS 2016
doi:10.1016/j.procs.2016.09.271

1. Introduction

Western Kazakhstan is region of great interest for SAR interferometry, because it can be subsided due to hydrocarbon extraction. One of the biggest in western Kazakhstan is Karazhanbas field (KBM). KBM is a giant shallow heavy oilfield, located on the Buzachi Peninsula (within 30x6 km onshore part), in the northern Caspian Sea. The largest shallow viscous oil field was discovered in 1974. The volume of production is more than 2 million tons of oil per year. From geological point of view, the Buzachi Peninsula contains a complex fault system with a large major fault zone[1]. According to the official seismic zoning map of Kazakhstan this region belongs to the zone of calm seismic regime. However, analysis of scientific papers published in the recent years gives assumption to consider that the western Kazakhstan is situated in a region with a risk of high seismicity[2]. Nowadays in order to reduce the risk of exploitation of fields apart from the conventional approaches (leveling, satellite navigation) SAR Interferometry techniques have been used widely. Results of the radar interferometry technology allow not only to detect subsidence movements and/or uplift and monitor progress of deformation over long period of time. Also it helps to predict annual subsidence rate and to carry out an assessment of possible damages of the region's infrastructure.

Nomenclature

SAR	Synthetic Aperture Radar
ASAR	Advanced Synthetic Aperture Radar
StaMPS/MTI	Stanford Method for Persistent Scatterers Multi-Temporal InSAR
PS	Persistent Scatterers
SBAS	Small Baseline Subset

2. Investigation of ESA archive data and metodology

Currently available software packages for interferometric data processing implement full cycle and/or the individual steps. The commercial software usually provides fully automated stages of interferometric processing for huge dataset. However, advanced user cannot contribute improvement of the processing steps in the commercial software, whereas the open-source software as StaMPS allows it.

Envisat archive data has been processed using StaMPS/MTI (Stanford Method for Persistent Scatterers/ Multi-temporal InSAR)[3]. StaMPS/MTI is an improved and expanded version of the software package STAMPS, that implements an InSAR persistent scatterer (PS), a small baseline method (SBAS) and a combined multi-temporal InSAR method. Thirty four descending ASAR acquisitions (track 192) spanning the period between 2004 and 2009 (Fig. 1) were used (Table 1).

Table 1. Satellite data stacks of Karazhanbas field

No.	Acquistion date	Orbit	B⊥(m)	Doppler diff. (Hz)	No.	Acquistion date	Orbit	B⊥(m)	Doppler diff. (Hz)
1	25Aug2003	7761	x	x	18	23Oct2006	24294	-597.324	12.6773
2	31May2004	11769	219.111	28.7157	19	27Nov2006	24795	-174.786	-8.40789
3	31Jan2005	15276	-258.849	34.7801	20	01Jan2007	25296	285.102	0.554581
4	07Mar2005	15777	68.3869	30.7402	21	05Feb2007	25797	-418.199	12.961
5	11Apr2005	16278	-146.611	29.6844	22	12Mar 2007	26298	277.616	18.6929
6	16May2005	16779	129.566	39.4788	23	16Apr2007	26799	-384.644	13.4045
7	20Jun2005	17280	145.172	41.6184	24	21May 2007	27300	-221.34	12.0966
8	25Jul 2005	17781	355.871	36.5573	25	25Jun 2007	27801	-164.834	10.5908
9	29Aug2005	18282	531.458	36.4593	26	30Jul 2007	28302	-219.135	11.1882
10	03Oct2005	18783	-544.218	-8.57663	27	03Sep 2007	28803	196.812	15.6385
11	07Nov2005	19284	480.826	-23.906	28	08Oct 2007	29304	-407.974	18.8089
12	12Dec2005	19785	-57.7348	-13.8972	29	12Nov 2007	29805	102.953	-2.16634

13	01May2006	21789	0	0	30	17Dec 2007	30306	-497.89	4.29172
14	05Jun2006	22290	-687.535	4.1361	31	22Sep2008	34314	-391.852	16.9782
15	10Jul2006	22791	620.674	2.94594	32	27Oct2008	34815	-93.1524	9.96795
16	14Aug2006	23292	695.062	4.09574	32	05 Jan 2009	35817	-411.415	17.5865
17	18Sep2006	23793	-1103.37	6.38608	34	09Feb2009	36318	-411.415	18.946

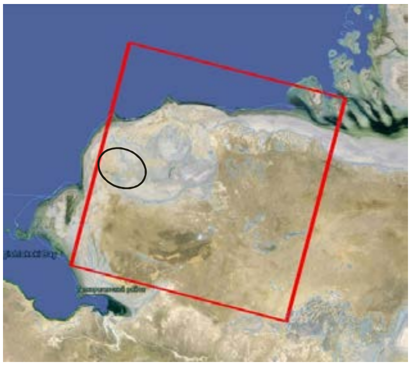

Fig. 1. Study area

StaMPS/MTI (Stanford Method for Persistent Scatterers/ Multi-temporal InSAR) method is different from the method of PSInSAR[4] approach to the selection of PS candidates.

Standard chain of the stages of interferometric processing in StaMPS/MTI[5]:

- Interferogram generation
- Phase stability estimation
- PS detection
- Displacement estimation

3. Results

Fig.2 shows the outcomes of the PS and SBAS processing, where indicated subsidence can be potentially associated with oil field development. The results over field show slow displacement trends of ± 20 mm/yr and show good agreement with each other.

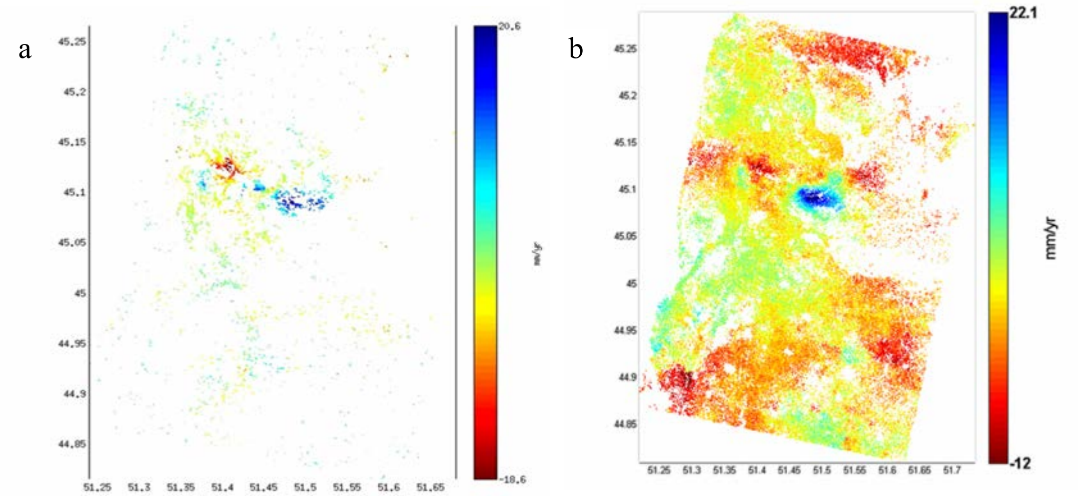

Fig. 2. (a) Persistent Scatterers (PS) result; (b) Small Baseline Subset (SBAS) results

According to the results of PS, as shown in Figure 2a, the 6130 PS points with high coherence signal have been identified, while 72 488 PS points have been selected by SBAS method. For further analysis detected SBAS points were interpolated by IDW (Inverse Distance Weighted) method in the ArcGIS software (fig. 3).

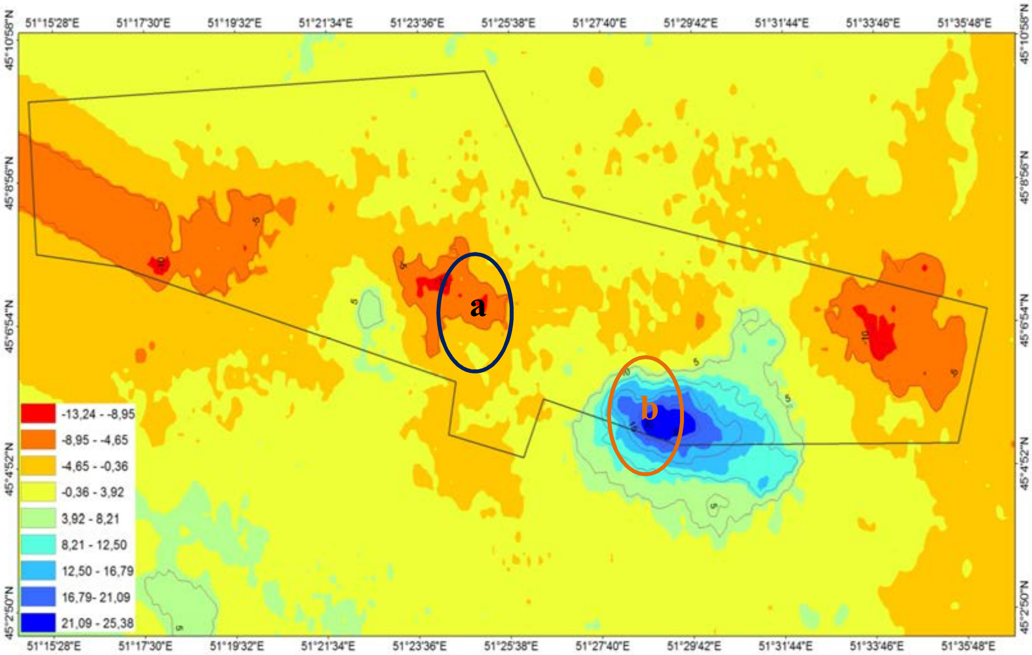

Fig. 3. Interpolated vertical displacement map of Karazhanbas field, velocity (mm/year)
For deformations in circled areas (a,b) shown graphs in Fig.4-5.

The processing of archived data using StaMPS methods detected few unstable zones at licence block of the field. There is high-amplitude subsidence of the earth's surface in the south-eastern and central parts.. As it can be seen from the Fig. 4,the graph for circled zone in Figure 3 PS points into the 100 meters radius characterized by subsidence with amplitude of -40 mm.

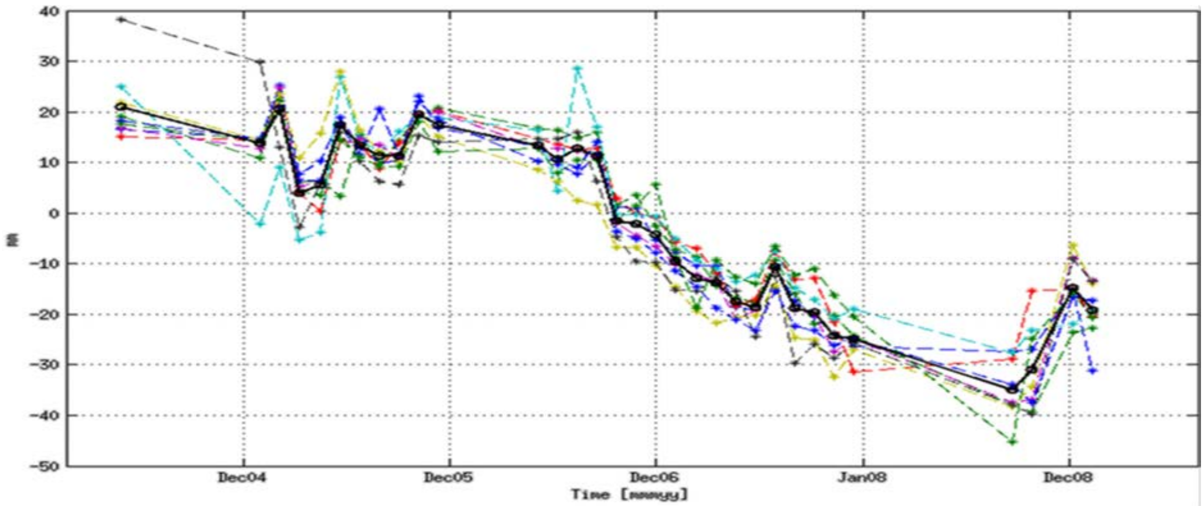

Fig. 4. The subsidence rate of PS (circle a)

Majority of subsidence in the field area affected by oil and gas activities[6]. The verification of the SAR -interferometry results with ground-based observations showed a accurate correlation. There is uplift zone at a rate of 20 mm per year for the observation period. The authors[6,7] assumed that the detected uplift zone associated with the activity of the mud volcano- see figure 5. However, this assumption is not confirmed.

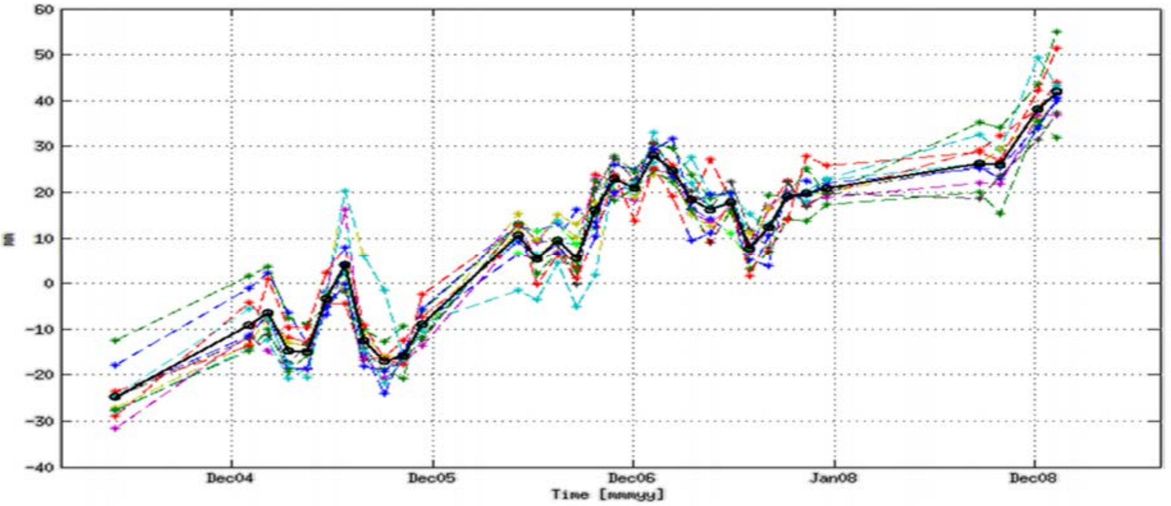

Fig. 5. The subsidence rate of PS (circle b)

4. Conclusion

From the archived ENVISAT data processing it might be concluded that there are various patches of area having significant displacement over the 5 years of observation period. In further, Sentinel 1A images will be used to observe the geodynamic activity of the geological environment of the field area with more precise estimation for this study.

Acknowledgements

Authors acknowledge ESA (project ID 29297) who kindly supplied us with the SAR data for this study. Project was financially supported by Republican Budget Program 002 “Applied Scientific Research in the Field of Space Activity” within the project “Develop a methodology for integrated monitoring of geodynamic processes in the oil-bearing areas of the Caspian region based on ground-space research data”.

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